APPLICATION

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TITLE: MULTIBAND MIMO-BASED 3G W-CDMA AND UWB COMMUNICATIONS

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MULTIBAND MIMO-BASED 3G W-CDMA AND UWB COMMUNICATIONS

Background

This invention is generally relative to a multiband Multiple-Input-Multiple-Output (MIMO)-base Third Generation (3G) Wideband Code Division Multiple Access (W-CDMA) and Ultra Wideband (UWB) Communications for a wireless and fixed wireless communication.

A MIMO is a multiple-input-multiple-output as a wireless link and is also a space-time signal processing that a natural dimensional of transmitting data is complemented with a spatial dimension inherent in the use of multiple spatially distributed antennas. In addition, the MIMO is able to turn multipath propagation into benefit for a user. In a MIMO system, signals on the transmit antennas at one-end and the receiver antennas at the other-end are integrated in such a way that a quality of bit error rate (BER) or a data rate of the communication for each user or a transmitting distance is improved, thereby increasing a communication network's quality of service.

The 3G is defined to allow the subscriber to access the World Wide Web or to perform file transfers over packet data connections capable of providing 144 kbps and 384 kbps for mobility, and 2 Mbps in an indoor environment. The W-CDMA is a wideband, spread spectrum radio interface that uses CDMA technology to meet the needs for the 3G of wireless communication systems. The W-CDMA (also known as

CDMA2000) supports for a wide range of radio frequency (RF) channel bandwidths from 1.25 MHz to 15 MHz with operating of 1.90 GHz band, where the channel sizes of 1, 3, 6, 9, and 12×1.25 MHz. The wide channels of the W-CDMA offer any combination of higher data rates, increase total capacity and/or increase range. The W-CDMA also employs a single carrier and a multicarrier system, which can be deployed as an overlay over one or more existing the second generation of TIA/EIA-95B 1.25 MHz channels. In the multicarrier system, modulation symbols are de-multiplexed onto N separate 1.25 MHz carrier. Each carrier is spread with a 1.2288 Mcps chip rate.

With regard to the UWB communications, U.S. Federal Communications Commission (FCC) released a revision of Part 15 of Commission's rules for UWB transmission systems to permit the marketing and operation of certain types of new products incorporating UWB technology on April 22, 2002. UWB communication devices can operate using spectrum occupied by existing radio service without causing interference, thereby permitting scare spectrum resources to be used more efficiently. UWB communication devices can offer significant benefits for Government, public safety, businesses and consumers under an unlicensed basis of operation spectrum.

FCC is adapting unwanted emission limits for the UWB communication devices that are significantly more stringent

than those imposed on other Part 15 devices. For the indoor UWB operation, FCC provides a wide variety of UWB communication devices, such as high-speed home and business networking devices under the Part 15 of the Commission's rules subject to certain frequency and power limitations. However, the UWB communication devices must operate in the frequency band ranges from 3.1 GHz to 10.6 GHz, and have an emission of -10 dBm for the indoor UWB operation. In addition, the UWB communication devices should also satisfy the Part 15.209 limit for the frequency band below 960 MHz. Table 1 lists the FCC restriction of the emission masks (dBm) along with the frequencies (GHz) for the UWB communication devices in the indoor environment.

Table 1

Frequency (MHz)	EIRP (dBm)
0-960	-41.3
960-1610	-75.3
1610-1990	-53.3
1990-3100	-51.3
3100-10600	-41.3
Above 10600	-51.3

The UWB communication devices are defined as any devices where the fractional bandwidth is greater than 0.25 based on the formula as follows:

$$FB = 2\left(\frac{f_H - f_L}{f_H + f_L}\right), \qquad (1)$$

where f_H is the upper frequency of -10 dBm emission points, and f_L is the lower frequency of -10 dBm emission points. A center transmission frequency F_c of the UWB communication devices is defined as the average of the upper and lower -10 dBm points as follows:

$$F_C = \frac{f_H - f_L}{2}. \qquad (2)$$

Furthermore, a minimum frequency bandwidth of 500 MHz must be used for the indoor UWB communication devices regardless of center frequencies.

The UWB communication devices can be used for wireless broadband communications within a short-distance range, particularly for a very high-speed data transmission suitable for broadband access to networks in the indoor environment.

The multiband MIMO-based 3G W-CDMA and UWB communication transceiver system is disclosed herein according to some embodiments of the present invention. The invention system includes a 3G W-CDMA base station, and a UWB base station, and *P*-user dual-mode portable station of the 3G W-CDMA and UWB communication devices. The base station of the 3G W-CDMA has a multicarrier for 12 channels with a total of 15-MHz frequency bandwidth at the center of 1.9 GHz frequency band, and employs four antennas at the transmitter and receiver. On the other hand, the base station of the UWB communication in the indoor environment

uses a multicarrier for four multibands with a total of 2.048-GHz frequency bandwidth in the frequency range from 3.1 GHz to 5.15 GHz, and also employs four antennas at the transmitter and receiver. Each of the multibands in the UWB communications has a 512-MHz frequency bandwidth with use of an OFDM modulation. For the 3G W-CDMA and UWB communication portable stations, each of the dual-mode portable stations of the 3G W-CDMA and UWB communication devices uses two antennas, and shares some of common components, such as A/D and D/A converters, memory, etc. The 3G W-CDMA in the dual-mode portable stations uses 12 channels with each channel of 1.25 MHz, has a multicarrier, and is able to transmit a data rate more than 2 Mcps, while the UWB employs four multiband-based multicarrier OFDM with each of multiband of 512 MHz, and can transmit a data rate up to 1.5872 Gbps. In addition, all of the dual-mode portable station use a direct sequence spread spectrum (DSSS), which is a pseudorandom (PN) sequence to spread a user signal. The DSSS is used to separate signals coming from multiuser. Thus, the multiple access interference (MAI) among multiuser can be avoided when a set of PN sequences is designed with as low cross-correlation as possible.

The OFDM is an orthogonal multicarrier modulation technique that has its capability of multifold increasing symbol duration. With increasing the number of subcarriers

in the OFDM modulation, the frequency selectivity of a channel may be reduced so that each subcarrier experiences flat fading for the UWB communications. Thus, the OFDM approach is a particular useful for the UWB communication over a short-range fading channel.

The present invention of the multiband MIMO-based 3G W-CDMA and UWB communications utilizes both benefits of the 3G W-CDMA wireless phones and the UWB wireless broadband communication. Such a dual-mode device not only can transmit the packet data in a form of wireless phone but also can use as a very-high speed wireless broadband Internet device to transmit and receive data, image, video, video game, music, and stock graph, etc., in a real-time. Thus, there is a continuing need of the multiband MIMO-based 3G W-CDMA and UWB communication transceiver system for delivering a very-high data rate with a capability of flexibility and scalability in a combination form of the wireless and fixed wireless environment.

Summary

In accordance with one aspect, a multiband MIMO-based dual-mode portable station of 3G W-CDMA and UWB communication receiver comprises a MIMO-based dual-mode 3G W-CDMA and UWB filtering and multicarrier RF section, a 3G W-CDMA baseband processor, an UWB OFDM multiband baseband

processor, a 3G W-CDMA and UWB OFDM multiband control processor, and a multiple antenna unit.

Other aspects are set forth in the accompanying detailed description and claims.

Brief Description of the Drawings

FIG. 1 is a block diagram of showing a multiband MIMO-based 3G W-CDMA and UWB communication transceiver system including *P*-user dual-mode portable station of 3G W-CDMA and UWB, and two separate base stations of the 3G W-CDMA and UWB communication according to some embodiments.

FIG. 2 is a block diagram of showing a MIMO-based 3G W-CDMA base station with employing four antennas according to some embodiments.

FIG. 3 is a detailed block diagram of showing a 3G W-CDMA baseband processor of the base station according to some embodiments.

FIG. 4 is a detailed block of showing a MIMO-based 3G W-CDMA filtering and multicarrier RF section according to some embodiments.

FIG. 5 is a detailed block diagram of showing a 3G W-CDMA mapping, spreading, and filtering section according to some embodiments.

FIG. 6 is a detailed block diagram of showing a 3G W-CDMA analog filtering and multicarrier modulation section according to some embodiments.

FIG. 7 is a block diagram of showing a MIMO-based UWB base station according to some embodiments.

FIG. 8 is a detailed block diagram of showing an UWB base station according to some embodiments.

FIG. 9 is a detailed block diagram of showing a MIMO-based UWB spreading and filtering section according to some embodiments.

FIG. 10 is a detailed block diagram of showing a MIMO-based UWB modulation and multicarrier RF section according to some embodiments.

FIG. 11 is a frequency spectrum output of the MIMO-based UWB base station transmitter for the indoor operation according to one embodiment.

FIG. 12 is a block diagram of showing a 3G W-CDMA and UWB portable station for a single user according to some embodiments.

FIG. 13 is a detailed block diagram of showing a MIMO-based dual-mode 3G W-CDMA and UWB filtering and multicarrier RF section according to some embodiments.

FIG. 14 is a detailed block diagram of showing a 3G W-CDMA down converter and demodulation according to some embodiments.

FIG. 15 is a detailed block diagram of showing an UWB multiband down converter and demodulation according to some embodiments.

FIG. 16 is a detailed block diagram of showing an analog-to-digital converter according to some embodiments.

FIG. 17 is a detailed block diagram of showing a 3G W-CDMA baseband processor in the dual-mode portable station according to some embodiments.

FIG. 18 is a detailed block diagram of showing a 3G W-CDMA multiband rake receiver and decoder unit according to some embodiments.

FIG. 19 is a detailed block diagram of showing a UWB OFDM multiband baseband processor according to some embodiments.

FIG. 20 is a detailed block diagram of showing a combination section of a digital receiver filter unit, a multiband despreading unit, and a TEQ unit according to some embodiments.

FIG. 21 is a detailed block diagram of showing a combination section of a FFT unit and a FEQ unit according to some embodiments.

FIG. 22 is a detailed block diagram of showing a despreading, deinterleaver, and decoding unit according to some embodiments.

Detailed Description

Some embodiments described herein are directed to the multiband MIMO-based 3G W-CDMA and UWB transceiver system for a wireless and fixed wireless communication. Such a dual-mode transceiver system may be implemented in

hardware, such as in an Application Specific Integrated Circuits (ASIC), digital signal processor, field programmable gate array (FPGA), software, or a combination of hardware and software.

Multiuser MIMO-Based 3G W-CDMA and UWB System

A multiuser MIMO-based 3G W-CDMA and UWB system 100 for the wireless and fixed wireless communication is shown in FIG. 1 in accordance with one embodiment of the present invention. Dual-mode 3G W-CDMA and UWB portable stations of 110a to 110p can simultaneously communicate with either a MIMO-based 3G W-CDMA base station 140 or a MIMO-based UWB base station 170 to transmit and to receive information data. The dual-mode 3G W-CDMA and UWB portable station 110a transmits and receives the 3G W-CDMA or the UWB information data through its two antennas of $120a_1$ and $120a_2$. The base station of the 3G W-CDMA 140 or the UWB base station 170 communicates with the dual-mode 3G W-CDMA and UWB portable station 110a through the 3G W-CDMA's four antennas of 130a to 130d or through the UWB's four antennas of 160a to 160d, respectively. In a similar way, other dual-mode 3G W-CDMA and UWB portable stations of 110b to 110p also transmit and receive the information data through their antennas of $120b_1$ and $120b_2$ to $120p_1$ and $120p_2$, respectively, and communicate with either the 3G W-CDMA base station 140 through the antennas of 130a to 130d or the UWB base station 170

through the antennas of 160a to 160d. The 3G W-CDMA base station 140 is coupled to a 3G W-CDMA network interface section 150 in which is connected with a 3G W-CDMA network 152. The UWB base station 170 is connected with an UWB network interface section 180 that is coupled to an UWB network 182.

The MIMO-based 3G W-CDMA base station 140 can transmit multiuser's information data at the same time. After scrambling with the long code corresponding to user p, the user data is de-multiplexed onto N carriers, where N equals to 3, 6, 9, or 12. On each carrier, the demultiplexed bits are mapped onto I and Q followed by using Walsh spreading. For reverse closed loop power control, the power control bits may be punctured onto the forward link channel at a rate of 800 Hz. Then, the signal on each carrier is orthogonally spread by the appropriate Walsh code function in such a way that a fixed chip rate of 1.2288 Mcps can be maintained per carrier. The Walsh code may differ on each carrier. The signal on each carrier is then complex PN spread followed by using a baseband filtering and BPSK or QPSK modulation. The 3G W-CDMA base station 140 can transmit and receive the data rate from 144 kbps to greater than 2 Mbps and supports for a wide range of RF channel bandwidths including 1.25 MHz, 3.75 MHz, 7.5 MHz, 11.25 MHz, and 15 MHz.

The MIMO-based UWB base station 170, with knowing all of the UWB PN sequences of the dual-mode 3G W-CDMA and UWB portable stations of 110a to 110p, can transmit and receive all of the UWB information data from all of the dual-mode 3G W-CDMA and UWB portable stations of 110a to 110p by spreading and despreading of the user PN sequences on the multiband. The MIMO-based UWB base station 170 uses a BPSK or a QPSK modulation and a carrier for each of the multiband to transmit and to receive the information data rate of 396.8 Mbps on one frequency band. As a result, the MIMO-based UWB base station 170 can simultaneously transmit and/or receive the maximum data rate up to 1.5872 Gbps by using all of the four frequency bands. In addition, the UWB base station 170 is able to transmit the data rate with an enhancement of a longer range due to use the multiple antennas.

3G W-CDMA Base Station Transmitter Architecture

FIG. 2 is a block diagram 200 of showing the MIMO-based 3G W-CDMA base station 140 according to some embodiments. The MIMO-based 3G W-CDMA base station 140 includes a 3G W-CDMA baseband processor 210, a MIMO-based 3G W-CDMA filtering and multicarrier RF section 220 coupled to four antennas of 130a to 130d, and a 3G W-CDMA control processor 230. The 3G W-CDMA baseband processor 210 deals with a multiuser digital signal processing of a physical

layer including turbo or convolution encoder and decoder, block interleaver and deinterleaver, spreading and dispreading. The MIMO-based 3G W-CDMA filtering and multicarrier RF section 220 provides filtering, modulation, and transmits W-CDMA signal through the antennas of 130a to 130d. The 3G W-CDMA control processor 230 supports a data frame information, and controls the 3G W-CDMA baseband processor 210 and the MIMO-based 3G W-CDMA filtering and multicarrier RF section 220.

The MIMO-based 3G W-CDMA base station 140 is able to transmit and receive multiuser information data through multichannel with multicarrier simultaneously. There are a total of 12 multicarriers for a wide range of RF channel bandwidths of 1.25 MHz, 3.75 MHz, 7.5 MHz, 11.25 MHz, and 15 MHz. The signal on each carrier is orthogonally spread by the appropriate Walsh code at the chip rate of 1.2288 Mcps. Then, the signal on each carrier is filtered and modulated by using the baseband filtering and BPSK or QPSK modulation. The MIMO-based 3G W-CDMA base station 140 can transmit and receive the data rate from 144 kbps to greater than 2 Mbps.

Referring to FIG. 3 is a detailed block diagram 300 of showing the 3G W-CDMA baseband processor 210 according to some embodiments. A turbo or convolution encoder 310 that is used to encode the user information data is coupled to a symbol repetition 320. The symbol repetition 320 can repeat

a frame symbol data with 2-time, 4-time or 8-time. The output of the symbol repetition 320 is interleaved by using a block interleaver 330. The output data of the block interleaver 330 is scrambled with a long code from a bit selector 360 by using a XOR 370. A long code mask for user *p* 340 is coupled to a long code generator 350 that is connected with a bit selector 360. The scrambled data of the XOR 370 output is demultiplexed onto 12 parallel data with label of d_1 to d_{12} by using a demultiplexer 380.

FIG. 4 is a block diagram 400 of showing the MIMO-based 3G W-CDMA filtering and multicarrier RF section 220 according to some embodiments. The MIMO-based 3G W-CDMA filtering and multicarrier RF section 220 includes a 3G W-CDMA mapping spreading and filtering 410 and a 3G W-CDMA analog filtering and multicarrier modulation 420. The 3G W-CDMA mapping spreading and filtering 410 is coupled to the 3G W-CDMA analog filtering and multicarrier modulation 420. The 12 parallel signals of d_1 to d_{12} are passed through the 3G W-CDMA mapping spreading and filtering 410 to produce 12 parallel output signals, which are used as the input signals for the 3G W-CDMA analog filtering and multicarrier modulation 420. Then the 3G W-CDMA analog filtering and multicarrier modulation 420 produce four parallel signals for the transmitter through four antennas of 130a to 130d.

Referring to FIG. 5 is a detailed block diagram 500 of showing the 3G W-CDMA mapping, spreading and filtering 410

according to some embodiments. The 12 parallel input signals of d_1 to d_{12} are passed through 12 MUX and IQ mapping units of 510a to 510m. The output *I* and *Q* signals of the MUX and IQ mapping units of 510a to 510m are spread by using Walsh codes of W_{m1} to W_{m12}, respectively. Then signals are complex PN spread by using complex PN spreading units of 530a to 530m, followed by baseband filters of $540a_1$ and $540a_2$ to $540m_1$ and $540m_2$. Analog-to-digital (A/D) converter units of $550a_1$ and $550a_2$ to $550m_1$ to $550m_2$ convert all of the digital signals of the baseband filter outputs of $540a_1$ and $540a_2$ to $540m_1$ and $540m_2$ into parallel analog signals of a_{11} and a_{12} to a_{121} and a_{122}.

Referring to FIG. 6 is a detailed block diagram 600 of showing the 3G W-CDMA analog filtering and multicarrier modulation 420 according to some embodiments. The input signals of a_{11} and a_{12} to a_{121} and a_{122} are in parallel passed through analog filters of $610a_1$ and $610a_2$ to $610m_1$ and $610m_2$ to produce reconstructed analog signals. Each pair of the output signals of the analog filters of $610a_1$ and $610a_2$ to $610m_1$ and $610m_2$ is performed QPSK modulation with multicarrier by using each pair of multipliers $620a_1$ and $620a_2$ and one addition 630a, to multipliers $620m_1$ and $620m_2$ and one addition 630m, respectively. The 12 QPSK signal with multicarrier are grouped together into four signals by using four additions of 640a to 640d, respectively,

followed by four baseband filters (BPF) of 650a to 650d to produce signals for power amplifier and antennas.

FIG. 7 is a block diagram 700 of showing the MIMO-based UWB base station 170 according to some embodiments. An UWB baseband processor 710 that performs convolution encoder and decoder, interleaver and deinterleaver, and IFFT and FFT functions is coupled to a MIMO-based UWB spreading and filtering 720, followed by a MIMO-based UWB modulation and multicarrier RF section 730. The MIMO-based UWB modulation and multicarrier RF section 730 is connected with four antennas of 160a to 160d. An UWB control processor 740 is used to control frame information and control entire process among the units of the MIMO-based UWB base station 170, the MIMO-based UWB spreading and filtering 720, and MIMO-based UWB modulation and multicarrier RF section 730.

Referring to FIG. 8 is a detailed block diagram 800 of showing the UWB baseband processor 710 according to some embodiments. There are a number of *p* users with a user-1 bitstream 810a to a user-*p* bitstream 810p, respectively. The user-1 bitstream 810a is coupled to a 1/2-rate convolution encoder 812a in which is connected to an interleaver 814a. Using a unique PN sequence of a user-1 key 822a spreads the output sequence of the interleaver 814a. In a similar way, the user-*p* bitstream 810p is coupled to the 1/2-rate convolution encoder 812p that is

connected to the interleaver 814p. Using the unique PN sequence of the user-p key 822p spreads the output sequences of the interleaver 814p. All of the PN sequences of the user-1 key 822a to the user-*p* key 822p are orthogonal each other. This means that a cross-correlation between one PN sequence and other PN sequences is almost zero, while a self-correlation of a user PN sequence is almost equal to one. Then, the *p* output sequences from the interleaver 814a to the interleaver 814p in a parallel operation are added together to form a serial sequence output by using a sum over block duration 830. The serial output of the sum over block duration 830 is converted into four parallel sequences by using a polyphase-based multiband 840. Thus, the first of the output sequence from the polyphase-based multiband 840 is converted into a 512-parallel sequence by using an S/P 850a. The 512-parallel sequence is formed to 512-parallel complex sequence with symmetric conjugate. The 512-parallel complex sequence is passed through an IFFT 852a to produce a 1024-parallel real sequence. The IFFT 852a is coupled to a guard 854a to insert 256 samples as a guard interval for the output sequence of the IFFT 852a. As a result, the output of the guard 854a is a 1280-parallel real sequence. Then, the outputs of the guard 854a are used to form a serial signal p_1 by using a P/S 856a. In the same way, the fourth of the output sequence from the polyphase-based multiband 840 is

converted into a 512-parallel sequence by using an S/P 850k. The 512-parallel sequence is formed to 512-parallel complex sequence with symmetric conjugate. The 512-parallel complex sequence is passed through an IFFT 852d to produce a 1024-parallel real sequence. The IFFT 852d is coupled to a guard 854d to insert 256 samples as a guard interval for the output sequence of the IFFT 852d. Thus, the output of the guard 854d is a 1280-parallel real sequence. The guard interval is used to avoid an intersymbol interference (ISI) between IFFT frames. Finally, the outputs of the guard 854d are used to form a serial signal p_4 by using a P/S 856d.

The data rate-dependent parameters of the 1024-point IFFT operation 852 is listed in Table 2 for each of the multi-frequency bands:

Table 2

Four band frequency data rate (Gbits/s)	One frequency band data rate (Mbits/s)	Modulation	Coding rate	Coded bits per sub-carrier	Coded bits per OFDM symbol	Data bits per OFDM symbol
0.7936	198.4	BPSK	1/2	1	992	496
1.5872	396.8	QPSK	1/2	2	1984	992

The corresponding 1024-point IFFT of detailed timing-related parameters for each of the multi-frequency bands is listed in Table 3:

Table 3

Parameters	Descriptions	Value
N_{ds}	Number of data subcarriers	992
N_{ps}	Number of pilot subcarriers	8
N_{ts}	Number of total subcarriers	1000
D_{fs}	Frequency spacing for subcarrier (512MHz/1024)	0.5 MHz
T_{FFT}	IFFT/FFT period (1/ D_{fs})	2.0 μs
T_{gd}	Guard duration ($T_{FFT}/4$)	0.5 μs
T_{signal}	Duration of the signal BPSK-OFDM symbol (T_{FFT} + T_{gd})	2.5 μs
T_{sym}	Symbol interval (T_{FFT} + T_{gd})	2.5 μs
T_{short}	Short duration of training sequence ($10 \times T_{FFT}/4$)	5.0 μs
T_{gd2}	Training symbol guard duration ($T_{FFT}/2$)	1.0 μs
T_{long}	Long duration of training sequence ($2 \times T_{FFT}$ + T_{gd2})	5.0 μs
$T_{preamble}$	Physical layer convergence procedure preamble duration (T_{short} + T_{long})	10.0 μs

Referring to FIG. 9 is a detailed block diagram 900 of showing the MIMO-based spreading and filtering section 720 according to some embodiments. There are four input signals of p_1 to p_4. The input signal of p_1 is demultiplexed by using a demultiplexer 910a to produce I and Q signals. The I and

Q signals are spread with an output sequence of a multiband spreading 930a by using XORs of 920a and 920b to produce spread I and Q signals, followed by two transmitter shaped filters of $940a_1$ and $940a_2$, respectively. Then, the output signals of the transmitter shaped filters of $940a_1$ and $940a_2$ are passed through two D/A converters of $950a_1$ and $950a_2$, followed by two analog filters of $960a_1$ and $960a_2$ to smooth the analog signals, respectively. In the same way, the input signal of p_4 is demultiplexed by using a demultiplexer 910d to produce I and Q signals. The I and Q signals are spread with an output sequence of a multiband spreading 930d by using XORs $920d_1$ and $920d_2$ to produce spread I and Q signals, followed by two transmitter shaped filters of $940d_1$ and $940d_2$, respectively. Then, the output signals of the transmitter shaped filters of $940d_1$ and $940d_2$ are passed through two D/A converters of $950d_1$ and $950d_2$, followed by two analog filters of $960d_1$ and $960d_2$ to smooth the analog signals, respectively. Thus, the MIMO-based spreading and filtering section of 720 convert four digital sequences onto four I and four Q spread analog signals with multicarrier for transmitter section.

Referring to FIG. 10 is a detailed block diagram 1000 of showing the MIMO-based UWB modulation and multicarrier RF section 730 according to some embodiments. The input signals of I_1 and Q_1 to I_4 and Q_4 are modulated in QPSK format with multicarrier by using multipliers of $1010a_1$ and

$1010a_2$ and an addition 1012a to $1010d_1$ and $1010d_2$ and an addition 1012d to produce RF signals of o_1 to o_2. Then, the signals of o_1 to o_2 are sum together to form four RF signals with multicarrier by using additions of 1020a to 1020d, followed by using analog bandpass filters of 1030a to 1030d. The output RF signals of the analog bandpass filters of 1030a to 1030d are passed through the power amplifier (PA) of 1040a to 1040d onto antennas.

Spectrums of MIMO-Based UWB Base Station Transmitter

FIG. 11 is an output frequency spectrum 1100 of the MIMO-based UWB base station communication transmitter, including four multi-frequency band spectrums of 1120, 1130, 1140 and 1150 according to some embodiments. A FCC emission limitation 1110 for the indoor UWB operation is also shown in FIG. 11. Each transmitter frequency bandwidth of all the multi-frequency band spectrums of 1120, 1130, 1140 and 1150 is 512 MHz and is fitted under the indoor FCC emission limitation 1110 with different carrier frequencies. The detail positions of each transmitter multi-frequency band spectrums (dBm) along with the center, lower and upper frequencies (GHz) as well as the channel frequency bandwidth (MHz) are listed in Table 4:

Table 4

Multichannel Label	Center Frequency (GHz)	Lower Frequency (GHz)	Upper Frequency (GHz)	Frequency Bandwidth (MHz)
1120	3.357	3.101	3.613	512
1130	3.869	3.613	4.125	512
1140	4.381	4.125	4.637	512
1150	4.893	4.637	5.149	512

During the indoor UWB operation, the MIMO-based UWB base station transmitters can avoid an interference with WLAN 802.11a lower U-NII frequency band in the frequency range of 5.15 GHz to 5.35 GHz since the highest spectrum of the MIMO-based UWB base station transmitter is at 5.149 GHz in which is lower than 5.15 GHz in WLAN 802.11a lower band.

Dual-Mode MIMO-based Receiver of 3G W-CDMA and UWB portable station

FIG. 12 is a block diagram 1200 of showing a dual-mode MIMO-based receiver of the 3G W-CDMA and UWB portable station 110a according to some embodiments. A dual-mode MIMO-based 3G W-CDMA, UWB filtering and multicarrier RF section 1210 receives RF signals from two antennas of $120a_1$ and $120a_2$ and converts RF signals to either 3G W-CDMA digital signals or UWB digital signals. The dual-mode MIMO-based 3G W-CDMA, UWB filtering and multicarrier RF section 1210 is coupled to a 3G W-CDMA baseband processor 1220 and

an UWB OFDM multiband baseband processor 1230. During the 3G W-CDMA mode, the 3G W-CDMA baseband processor 1220 receives the W-CDMA digital signals from the dual-mode MIMO-based 3G W-CDMA, UWB filtering and multicarrier RF section 1210 to perform digital filtering, demultiplexer, rake receiver, dispreading, deinterleaver, and decoding processes. During the UWB mode, the UWB OFDM multiband baseband processor 1230 receives the UWB digital signals from the dual-mode MIMO-based 3G W-CDMA, UWB filtering and multicarrier RF section 1210 to deal with digital filtering, multiband dispreading, time-domain equalizer (TEQ), FFT, frequency-domain equalizer (FEQ), dispreading, deinterleaver, and decoding. A 3G W-CDMA and UWB OFDM multiband control processor 1240 is used to control data flow among blocks of the dual-mode MIMO-based 3G W-CDMA, UWB filtering and multicarrier RF section 1210, the 3G W-CDMA baseband processor 1220, the UWB OFDM multiband baseband processor 1230, and a sharing memory bank 1250.

Referring to FIG. 13 is a detailed block diagram 1300 of showing the dual-mode MIMO-based 3G W-CDMA, UWB filtering and multicarrier RF section 1210 according to some embodiments. Two low noise amplifiers (LNA) of 1310a and 1310b receive RF signals from two antennas, respectively, and amplify RF signals. The LNA of 1310a and 1310b respectively connect with two automatic gain controls (AGC) of 1320a and 1320b, followed by two analog baseband

filters of 1330a and 1330b. Two outputs of the analog baseband filter 1330a are passed to two switch units of 1340 and 1344. In the same way, two outputs of the analog baseband filter 1330b are passed to the switch units of 1340 and 1344. During the 3G W-CDMA mode, two switches of 1342a and 1342b in the switch unit 1340 connect with the outputs from the analog baseband filters of 1330a and 1330b. The output signals, *a* and *b*, of the switch unit 1340 are passed into a 3G W-CDMA down converter and demodulation 1350 in which produces two analog baseband signals, g_1 and g_2, for an A/D unit 1370. During the UWB mode, two switches of 1346a and 1346b in the switch unit 1344 connect with the outputs from the analog baseband filters of 1330a and 1330b. The output signals, *c* and *d*, of the switch unit 1344 are passed into an UWB multiband down converter and demodulation 1360 that generates eight analog baseband signals, u_1, u_2, u_3, u_4, u_5, u_6, u_7, and u_8, for an A/D unit 1370.

Referring to FIG. 14 is a detailed block diagram 1400 of showing the 3G W-CDMA down converter and demodulation 1350 according to some embodiments. The input signals of *a* and *b* are sum together by using a 3G W-CDMA sum over a block duration 1410. The output signals of the 3G W-CDMA sum over the block duration 1410 convert into two parallel signals that are demodulated with multicarrier of 1420a and

1420b, followed by two channel select filters of 1430a and 1430b to produce desired signals of g_1 and g_2, respectively.

Referring to FIG. 15 is a detailed block diagram 1500 of showing the UWB multiband down converter and demodulation 1360 according to some embodiments. The input signals of c and d are sum together by using an UWB sum over the block duration 1510 to produce four parallel signals for four multiband down converters and demodulations of 1520a to 1520d. The multiband down converters and demodulations of 1520a to 1520d perform down converter and demodulation, and produce eight analog baseband signals of u_1 to u_8.

Referring to FIG. 16 is a detailed block diagram 1600 of showing the A/D unit 1370 according to some embodiments. There are two switch units of 1620 and 1640 and eight A/D converters of 1650a to 1650h, with a sampling frequency rate at 540 MHz. During the 3G W-CDMA mode, two switches of 1620 and 1640 connect to the input signals of g_1 and g_2, respectively. The outputs of the switches of 1610 and 1630 are passed into two A/D converters of 1650a and 1650b, with the sampling frequency rate at 540 MHz. This is 36 times oversampling for the 3G W-CDMA signals. Other A/D converters of 1650c to 1650h are rest. The output signals au_1 and au_2 of the A/D converters of 1650a and 1650b will be used in the W-CDMA baseband processor. During the UWB mode, the switches of 1620 and 1640 connect to the input signals

of u_1 and u_2, respectively. The outputs of the switches of 1610 and 1630, and input signals of u_3 to u_8 are in parallel passed onto eight A/D converters of 1650a to 1650h, where the sampling frequency rate is 540 MHz for all the A/D converters. The output signals of the A/D converters of 1650a to 1650h are referred to as au_1 to au_8, which will be used in the UWB baseband processor.

FIG. 17 is a detailed block diagram 1700 of showing the 3G W-CDMA baseband processor 1220 according to some embodiments. The input signals of au_1 and au_2 are passed through two digital filters of 1710a and 1710b, followed by two down samplings of 1720a and 1720b, respectively. The output signals of the down samplings of 1720a and 1720b are multiplexed by using a MUX 1730. Then, the output signal of the MUX 1730 is passed to a multiband rake receiver and decoder unit 1740 to produce user data stream.

Referring to FIG. 18 is a detailed block diagram 1800 of showing the multiband rake receiver and decoder unit 1740 according to some embodiments. The input signal is digitally demodulated to form 12 multiband baseband signals by using multipliers of 1810a to 1810m. The 12 multiband baseband signals are passed through 12 digital filters of 1820a to 1820m to produce the desired signals, followed by using 12 despreader and rake units of 1830a to 1830m. Then 12 parallel output signals of the despreader and rake units of 1830a to 1830m are multiplexed together by a MUX 1840 to

produce a serial signal. The serial signal is thus despread by using a long code sequence that is generated by using a long code generator 1852 based on a long code user-p mask 1850. The output signal of the despreader 1854 is deinterleaved by using a deinterleaver 1860, followed by using a desymbol repetition 1870 and a decoder 1880 to produce the user-p data stream.

FIG. 19 is a detailed block diagram 1900 of showing the UWB OFDM multiband baseband processor 1230 according to some embodiments. The eight input signals of au_1 to au_8 are passed through a digital receiver filter unit 1910, followed by a multiband dispreading unit 1920 and a TEQ unit 1930 to produce four parallel signals. The TEQ unit 1930 is used to reduce the length of cyclic prefix to a more manageable number without reducing performance significantly. In other words, the TEQ unit 1930 can produce a new target channel with a much smaller effective constraint length when concatenated with the channel. Thus, the outputs of the TEQ unit 1930 in parallel are passed through four S/Ps of 1940a to 1940d to produce parallel digital sequences. Each of the S/Ps of 1940a to 1940d produces 1280 parallel digital sequences for each of guard removing units of 1942a to 1942d. The guard removing units of 1942a to 1942d remove 256 samples from the 1280 parallel digital sequences of the S/Ps of 1940a to 1940d to produce 1024 parallel digital sequences, which are used as inputs

for FFT units of 1944a to 1944d. Each of the FFT units of 1944a to 1944d produces 512 frequency-domain signals that are used for frequency-domain equalizer (FEQ) units of 1946a to 1946d. The FEQ units of 1946a to 1946d are used to compensate for phase distortions, which are a result of phase offsets between the sampling clocks in the transmitter and the receiver of the MIMO-based multiband of the UWB communication transceiver. This is because the phases of the received outputs of the multiband FFT units of 1944a to 1944d are unlikely to be exactly the same as the phases of the transmitter symbols at the input to the IFFT units of 852a to 852d of the MIMO-based multiband of UWB base station transmitter as shown in FIG. 8. Thus, the outputs of the FEQ units of 1946a to 1946d are passed through a set of P/S units of 1948a to 1948d and a P/S 1950 to produce a serial sequence for all of the four multi-frequency bands. Thus, the output sequence of the P/S 1950 is used for a despreading, deinterleaver, and decoding unit 1960, which performs despreading, deinterleaving, and decoding for the MIMO-based multiband of the UWB mobile communication receiver.

Referring to FIG. 20 is a detailed block diagram 2000 of showing a combination 1970 of the digital receiver filter unit 1910, the multiband dispreading unit 1920, and the TEQ unit 1930 according to some embodiments. The eight input signals of au_1 to au_8 are in parallel passed through

the digital receiver filters of $2010a_1$ and $2010a_2$ to $2010d_1$ and $2010d_2$, respectively. The output signals of the digital receiver filters of $2010a_1$ and $2010a_2$ to $2010d_1$ and $2010d_2$ are despread by using XORs of $2020a_1$ and $2020a_2$ to $2020d_1$ and $2020d_2$ with the output sequences of multiband dispreading of 2030a to 2030d. Then, every pair of the output signals of the XOR of $2020a_1$ and $2020a_2$ to $2020d_1$ and $2020d_2$ are multiplexed together by using MUXs of 2040a to 2040d, followed by using TEQ of 2050a to 2050d.

FIG. 21 is a detailed block diagram 2100 of showing a combination 1980 including the FFT 1944 and the FEQ 1946 according to some embodiments. The FFT 1944 has a 1024-point input of real-value and produces a 512-point complex data with labels of 0 to 511, while a 512-point complex data with labels of 511 to 1023 is disable. The FFT 1944 with labels of 0 to 511 also contains 12 Nulls. So, the FFT 1944 produces a 500-point complex data for the FEQ 1946. The FEQ 1946 contains 500 equalizers of $2110a_1$ to $2110a_{500}$, 500 decision detectors of $2120a_1$ to $2120a_{500}$, and 500 subtractions of $2130a_1$ to $2130a_{500}$ that operate in parallel. Each of the equalizers of $2110a_1$ to $2110a_{500}$ has N-tap with adaptive capability. Each of the decision detectors of $2120a_1$ to $2120a_{500}$ is a multi-level threshold decision. Each of the subtractions of $2130a_1$ to $2130a_{500}$ performs subtracting between the output of each of the equalizers of $2110a_1$ to $2110a_{500}$ and the output of each of the decision

detectors of $2120a_1$ to $2120a_{500}$. The output of each of the subtraction of $2130a_1$ to $2130a_{500}$ is referred to an error signal, which is used to adjust the N-tap coefficients of the each of the equalizers of $2110a_1$ to $2110a_{500}$ by using an adaptive algorithm 2130.

The phases of the received outputs of the FFT 1944 do not have exactly the same as the phases of the transmitter symbols at the input to the IFFT units of 852a to 852d of the MIMO-based multiband of UWB base station transmitter as shown in FIG. 8. In addition, the phase responses have to consider the channel in which is coped with the TEQ 1930 as shown in FIG. 19. Thus, the FEQ 1946 in FIG. 21 is used to compensate for the phase distortion that is a result of a phase offset between the sampling clocks in the transmitter and the receiver of the MIMO-based multiband of the UWB communication transceiver. The FEQ 1946 also offers the additional benefit of received signal scaling before decoding since the FEQ 1946 can be used to adjust the gain of the FFT 1944 output so that the decision detectors of $2120a_1$ to $2120a_{500}$ can be set the same parameters for all subchannels regardless of the different subchannel attenuations.

FIG. 22 is a detailed block diagram 2200 of showing the despreading, deinterleaver, and decoding unit 1960 according to some embodiments. This unit 1960 includes a despreading 2210, a user-*i* key 2220, a deinterleaver 2230,

a Viterbi decoding 2240, and a user-*i* bitstream 2250. The input signal is despread with a spreading sequence of the user-i key 2220, which provides a unique key sequence, by using the despreading 2210. The despreading 2210 is a XOR operation to produce an encoded user-*i* data bitstream. This encoded user-*i* data bitstream is then deinterleaved by using the deinterleaver 2230 that is also coupled to the Viterbi decoding 2240. The Viterbi decoding 2240 decodes the encoded user-*i* data bitstream to produce an original transmitted user-*i* data bitstream that is stored into the user-*i* bitstream 2250.

While the present inventions have been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of these present inventions.

What is claimed is: